ATTACHMENT A

20 MATERIALS FOR SPECIAL APPLICATIONS

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This section was condensed from Metals Handbook, Ninth Edition, Volume 3, Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals, pages 595 to 822. For more detailed information on the topics covered herein, the reader is referred to the larger work.

Magnetically Soft Materials

Condensed from Metals Handbook, Ninth Edition, Volume 3, pages 597 to 614.

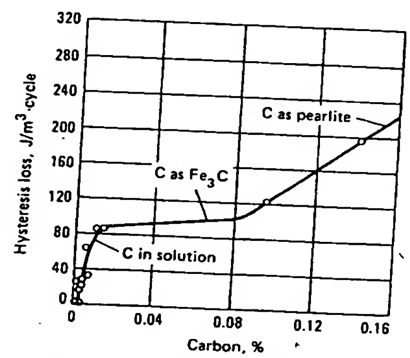
MAGNETICALLY SOFT MATERIALS are ferromagnetic materials that have little or no retentivity—that is, if they are magnetized in a magnetic field and then are removed from that field, they lose most, if not all, of the magnetism they exhibited while in the field.

The most important characteristics of magnetically soft materials are: (*a*) low hysteresis loss (easy domain movement during magnetization); (*b*) low eddy-current loss from electric currents induced by flux changes; (*c*) high magnetic permeability, and sometimes constant permeability at low field strengths; (*d*) high magnetic saturation induction; and (*e*) minimum or definite change in permeability with temperature in special applications. Cost, availability and ease of processing also influence final choice of material.

Magnetically soft materials made in large quantities include high-purity iron, low-carbon steels, silicon steels, iron-nickel alloys, iron-cobalt alloys, and ferrites.

Impurities. Ferromagnetic properties depend on crystal structure and composition. Carbon, sulfur, nitrogen and oxygen are especially deleterious to ferromagnetic properties because they distort the lattice of the crystal structure and even in small amounts may greatly interfere with easy movement of magnetic domains, which is the basis of such properties.

A similar disturbance caused by carbon and nitrogen, known as "aging," occurs when low solubility at room temperature causes the excess solute to precipitate slowly as small particles within grains. In irons and iron-silicon alloys,



Induction B = 1 tesla (10 000 gausses).

Fig. 1. Relationship between carbon content and hysteresis loss for unalloyed iron

carbon content preferably should be less than 0.003% for best permeability, low hysteresis loss and minimal aging. Figure 1 shows the relationship between carbon content and hysteresis loss for iron. Hysteresis loss is similarly related to sulfur and oxygen contents.

Grain Size. For most applications, grain size should be as large as possible for nonoriented materials (Fig. 2). In oriented grades of silicon steel, optimum magnetic properties are usually obtained with grain sizes of 2 to 10 mm depending on the degree of crystal orientation: increases in grain size above 10 mm are accompanied by significant increases in both domain-wall spacing and eddy-current losses.

Grain Orientation. All ferromagnetic crystals are magnetically anisotropic — that is, they have different magnetic properties in different crystallographic directions. In nickel, the direction of easiest magnetization is the cube diagonal ⟨111⟩; in iron it is the cube edge ⟨100⟩. Crystal orien-

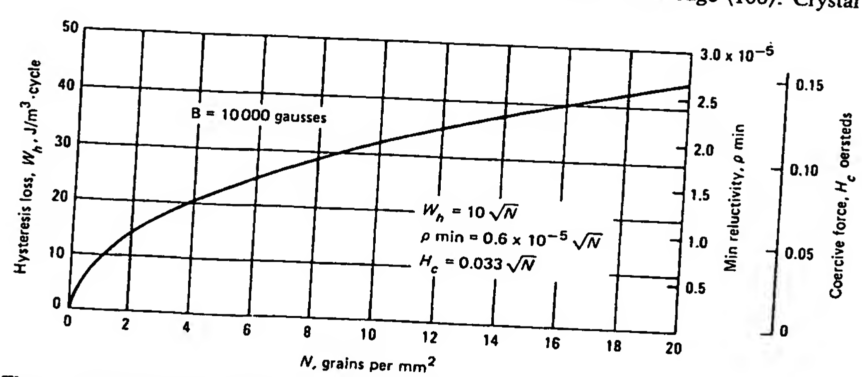


Fig. 2. Effect of grain size on magnetic properties of pure iron and silicon iron